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Effect of simulated ambient particulate matter exposure on performance, rectal temperature, and leukocytosis of young Spanish goats with or without tilmicodin phosphate¹

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ABSTRACT: Dust is an environmental stressor and can become extensive in agricultural production systems. Thirty-six female, Spanish goats (average BW 21.1 kg, SEM = 1.31; age = 4 mo) were randomly assigned to simulated dust events or no dust, with or without tilmicodin phosphate treatment in a 2 × 2 factorial arrangement of treatments to determine effects on performance, rectal temperature, and leukocyte changes. All goats were fed a standard growing diet (13.6% CP) consisting of 37% roughage and 63% concentrate (DM basis). Feed intake was measured daily, and BW (unshrunk) measured individually every 7 d. The tilmicodin-treated group received tilmicodin phosphate (10 mg/kg BW s.c.) before starting the study. Goats exposed to dust were enclosed as a group inside a canvas tent for 4 h each day and ground feed yard manure dust (mean particle size 100 μm) was aerosolized inside the tent to simulate a dust event. There was one single

dust event (Phase I) followed by rectal temperature measurement, and heparinized blood collection for complete cell counts at 0 (pretreatment), 4, 12, 20, 44, 68, and 210 h after dust exposure. This was followed by 21 d of chronic dust events (Phase II). The sampling procedures for Phase II were exactly the same as in Phase I, except that samples were obtained daily at 0 (before dust application), 4, 8, and 12 h after each dust event. Dust treatment had no effect ($P > 0.05$) on feed intake or ADG, but the gain:feed (G:F) ratio was lower ($P < 0.05$) in the control goats than the dust exposed group. Tilmicodin phosphate-treated goats had a higher ($P < 0.05$) G:F ratio than untreated goats. Dust exposure increased ($P < 0.002$), but tilmicodin treatment decreased ($P < 0.05$) rectal temperature at 4 and 8 h. Dust exposure increased ($P < 0.02$) blood lymphocyte counts compared with controls. These results suggest that simulated dust events altered rectal temperature and leukocyte counts of goats.

Key Words: Blood Cells, Dust, Goats, Performance, Tilmicodin Phosphate

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Introduction

Dust is an environmental stressor and could become extensive in certain areas of confined animal-feeding operations. Dust events are very common in agricultural production systems. Animal production, such as at large integrated poultry farms (Clark et al., 1983)

in the southeastern United States and at swine farms (Zeida et al., 1993) in the panhandle of Oklahoma and Texas, produces particulate matter into the environment. Several million tons of manure (Sweeten et al., 1988) are produced by confined animal feeding operations in a year. Dry manure produces dust particles (Sweeten et al., 1988), which were found to have a median aerodynamic equivalent particle size diameter of $9.5 \pm 1.5 \mu\text{m}$ when collected with standard high volume samplers and $6.9 \pm 0.8 \mu\text{m}$ when measured with particulate matter (PM₁₀) samplers (Sweeten et al., 1998) designed to measure particle sizes of 10 μm or smaller. The effects of manure particulate matter on animal performance and health are not well documented. However, there is concern that dust production might increase the incidence of bovine respiratory diseases, which account for 80% (Horton, 1984) of all calf deaths in commercial feed yards and result in economic losses estimated at \$800 to \$900 million an-

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Table 1. Composition of the diet fed to goats^a

Ingredient	Concentration, DM basis
Dehydrated alfalfa, %	18.4
Dent corn, %	52.1
Cottonseed hulls, %	18.2
Cottonseed meal, %	5.3
Beet molasses, %	3.9
Ammonium sulfate, %	0.99
Limestone, %	0.49
Sheep trace mineral premix, % ^b	0.02
Decoquinate, 30 mg/kg	0.05
Salt, %	0.49
Vitamin E (88,000 IU/kg)	0.02
Vitamin A (88 million IU/kg)	0.01
Calculated composition	
Dry matter, %	89.3
TDN, %	71.4
NE _m , Mcal/kg	1.66
NE _g , Mcal/kg	1.05
Crude protein, %	13.6
Calcium, %	0.62
Phosphorus, %	0.32
Potassium, %	1.25
Copper, mg/kg	14
Selenium, mg/kg	0.17
Zinc, mg/kg	39

^aThe diet was fed as pellets.

^bContained (as-fed basis): Mn 30,000 mg/kg; Zn 232,000 mg/kg; Fe 600 mg/kg; Se 20 mg/kg; Co 2,000 mg/kg; I 6,000 mg/kg.

nually (Chirase and Greene, 2001) and an additional loss of \$110 million annually in multiple processing (Smith et al., 1991). Knowledge of the role that dust events play on animal performance and health could provide critical information for livestock management, especially during dry environmental conditions. The present study evaluated the effects of simulated cattle feed yard manure dust/endotoxin continuously aerosolized over a 4-h period in two phases (single and chronic) on performance, rectal temperature and total white blood cell counts of weanling Spanish goats.

Materials and Methods

Animal Housing and Care

The protocol for this experiment was reviewed and approved by the Institutional Agricultural Animal Care and Use Committee (IAACUC) of the Cooperative Research, Educational and Extension Triangle (CREET), Amarillo, TX. The goats were cared for by acceptable practices outlined for agricultural research animals by the Federation of Animal Science Societies (FASS, 1999).

Thirty-six female Spanish goat weanlings (average BW 20 kg, SE = 1.31; age = 4 mo) were purchased locally from a producer. The goats were adapted to pens (215 cm long × 124 cm wide × 124 cm tall) for 14 d. Goats were fed a standard growing pelletized diet (Table 1) formulated to meet or exceed the growing requirements (NRC, 1981) of weanling goats. Before

the experiment began, all goats were treated for internal parasites using ivermectin (Ivomec; MSD AGVET, Merck and Co. Inc., Rahway, NJ) and Coccidia using a thiamine analog (Amprolium; MSD AGVET, Merck and Co. Inc.). Goats were stratified by initial BW and allotted randomly into groups (replicates) of three and housed in 12 indoor pens (pens/treatment), such that daily group feed consumption could be measured. Groups or pens of goats were assigned randomly to dust and tilmicosin phosphate treatments in a 2 × 2 factorial arrangement of treatments. In this experiment, pens were used in the statistical analysis as experimental units for performance and individual goats were sampling units for blood variables. All goats were fed once a day at 0800 to ad libitum intake. Water was available on an ad libitum basis. Daily feed intake (by pen) was measured for 49 d.

Manure Dust Preparation and Application and Endotoxin Assay

The feed yard manure dust was obtained by collecting manure from the feed yard pen surface after cattle had been removed. The dry manure was pulverized by passing it through 2-mm sieve roller drums (custom-fabricated at Bushland, TX). The dust was further passed through a series of standard soil sieves (E. H. Sargent & Co., Chicago, IL). Then the dust was ground smaller in an automatic soil grinder (Nasco, Fort Arkinson, WI). The dust (6 % moisture) was stored in covered buckets until used.

The dust particle sizes were determined by a Mastersizer 2000 (Malvern Instruments Inc., Southborough, ME), and the endotoxin concentration in the dust was determined by using the kinetic chromogenic semiquantitative *Limulus* amebocyte lysate assay (Williams and Halsey, 1997).

Eight filter holders (Millipore Swinnex filter holders, Millipore Corp., Bedford, MA) were equipped with 47-mm, 0.45-μm filters. These filters were used to determine the dust in the air of the tent. Vacuum pumps were used to collect 28.3 L of air/min. All gravimetric filter determinations were done in duplicate and averaged. The filters were preweighed and after 30 min weighed again to determine the quantity of dust per cubic meter in the tent.

The dust events were generated by enclosing dust-treated goats in a semi-airtight canvass tent (183 cm wide × 244 cm long × 213 cm tall) and the ground cattle feed yard manure dust (briefly described) dropped from a hopper into a jet mill (Jet-O-Mizer, Fluid Energy Processing and Equipment Co., Hatfield, PA) and was blown through a pipe into the tent where it exited through a set of baffles placed near the ceiling. Circulation of the dust was aided by electric fans, which also aided in keeping the inside of the tent cool (Purdy et al., 2002). The aerosolized dust in the tent created a dust suspension similar (by visual estimation) to those observed late in the evening at commercial cattle feed

yards. The speciation of the particles suspended inside the tent by shape and chemical composition are beyond the scope of this study.

Dust/endotoxin exposure treatments were applied in two phases and dust treatments were applied to goats as a group enclosed in the tent. A dust event in this study consisted of exposing goats to dust for 4 h (0800 to 1200), and there was only one dust event per day. We hypothesized that changes in performance and health would be observed after the first single dust event (Phase I). Following the single dust event, daily feed intake was measured, and rectal temperatures were measured at 0 (before dust/endotoxin application), 4, 12, 20, 44, 68, and 210 h. In addition, heparinized blood was obtained from all treatment groups at these times and used for total and differential white blood cell counts. Body weights (unshrunk) were measured every 7 d. Following the first dust event, and 7 d of rest (Phase I), there were a total of 21 dust events (chronic exposure, or Phase II) consisting of seven consecutive days of dust exposure followed by seven consecutive days of rest, in that order, until the end of the study. The sampling procedures used during Phase II were exactly the same as those used in Phase I, except that samples were obtained at 0 (before dust application), 4, 8, and 12 h on each day of dust application. The control goats were kept in a similar semi-airtight canvass tent at the other end of the barn and no dust was blown inside that tent. Also, the stress effects of the noise from the dust machine and fans were common to both groups.

Rectal temperature was used as a measurement of body core temperature (Cummins and Rosenquist, 1980). Following the initial single dust exposure period (Phase I), rectal temperatures were recorded at 0 (0800 before dust exposure), 4 (immediately after dust exposure), 12, 20, 44, 68, and 210 h after dust exposure. However, during the chronic dust exposure period (Phase II), rectal temperatures were recorded at 0, 4, 8, and 12 h after exposure on each day of dust exposure. Rectal temperatures were not recorded during rest periods of Phases I and II.

Statistical Analysis

The performance and rectal temperature data were analyzed using Proc Mixed in SAS (SAS Inst. Inc., Cary, NC). Fixed effects included in the model were dust treatment, tilmicosin treatment, day and hour, and their interactions. The random factor was a goat within pen. Time effects on rectal temperature and blood cell counts were included in the model and analyzed as double (day and hour) repeated measures. Also, whenever initial (d 0) rectal temperature and blood variables were different ($P < 0.05$), they were included in the model as covariates. The model of choice for these data was SP(POW) for spatial covariance structures (power), used to fit a matrix to the day and hour error variance and covariances. The

SP(POW) model type specification included unequal spacing for days and hours, and unequal variances. The degrees of freedom were calculated using the Kenward-Rogers specification. When the F-test was significant, means were separated by least squares means procedures of SAS.

Results and Discussion

Manure Dust Particle Sizing and Endotoxin Assay

The feed yard dust was analyzed dry by passing 1-g samples through the analyzer three times, which gave similar histograms. The particle sizes ranged from 0.89 to 356 μm with a mean of 100 μm . The feed yard dust contained 27 μg of endotoxin per gram of dust. The dust concentration in the tent averaged 51 mg/m^3 ($\text{SEM} = 10.74$). According to Duke (1955), the formula for calculating the tidal air, defined as the volume of air inspired or expired in one respiration is given as $\text{BW (g)} \times 0.0074 = \text{tidal air (mL)}$. Using this formula, the mean tidal air of each goat was calculated as $21,100 \text{ g} \times 0.0074 = 156.1 \text{ mL}$. Twenty is the normal ventilation rate (breaths/min) for sheep and goats (Duke, 1955). Thus, $20 \times 156.1 \text{ mL} = 3,122 \text{ mL/min}$ of air inspired. In 4 h, the ventilation rate was $3,122 \text{ mL} \times 240 \text{ min} = 749.3 \text{ L}$. Thus, each goat is capable of inspiring 749.3 L of air during each 4-h simulated dust event.

Animal Performance

There was no interaction ($P > 0.05$) between dust and tilmicosin phosphate treatments on final BW and feed intake during the chronic dust exposure period. The final BW of the goats were not different ($P > 0.05$) for either dust or tilmicosin phosphate treatment groups. Feed intake (1.08 vs. 1.05 kg/d; $\text{SEM} = 0.04$) and ADG (54.4 vs. 49.3 g/d; $\text{SEM} = 3.09$) of the goats exposed to dust were not different ($P > 0.05$) from the control goats, respectively. However, the G:F ratio was higher ($P < 0.05$) in the dust-treated group than controls (0.050 vs. 0.047; $\text{SEM} = 0.001$; respectively). In a similar study using market stressed steer calves (Chirase et al., 2000), there was an interaction ($P < 0.05$) between simulated dust exposure and tilmicosin phosphate treatment for ADG. The interaction occurred because steers treated with tilmicosin phosphate before dust exposure had greater ($P < 0.05$) ADG than those not treated with tilmicosin phosphate. In addition, the feed consumption of steers exposed to dust was 20% lower than those not exposed to dust.

Feed intake (1.07 vs. 1.06 kg/d; $\text{SEM} = 0.10$) and ADG (54.0 v. 49.7 g/d; $\text{SEM} = 3.12$) of tilmicosin phosphate-treated goats were not different ($P > 0.05$) from untreated goats, respectively. However, goats treated with tilmicosin had a higher ($P < 0.05$) G:F ratio than untreated goats (0.050 vs. 0.047; $\text{SEM} = 0.001$), suggesting that the tilmicosin treatment was effective at

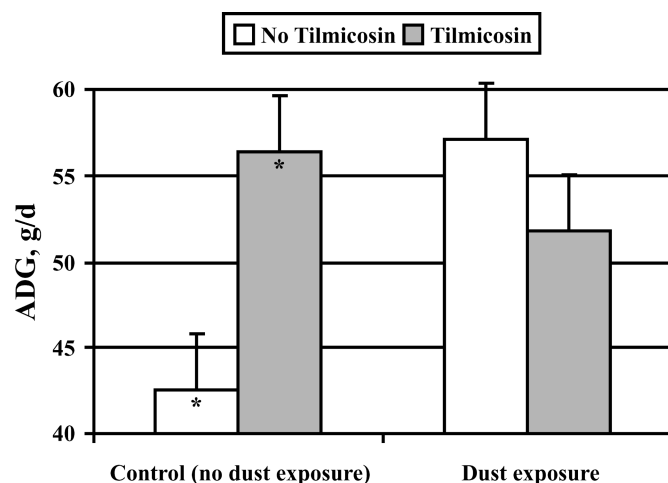


Figure 1. Effect of chronic cattle feed yard manure dust exposure and tilmicosin phosphate treatment on ADG (g/d) of young Spanish goats. Values indicated by asterisks within that treatment differ ($P < 0.05$).

improving the feed efficiency of the goats. In three receiving trials using beef calves purchased in Tennessee by Galyean et al. (1995), tilmicosin phosphate had no effect on daily DM intake, ADG, or feed-to-gain ratio in two of the trials when compared with untreated calves. However, in the third trial, tilmicosin phosphate treatment increased daily DM intake ($P < 0.05$) and ADG ($P < 0.01$), and lowered ($P < 0.03$) feed-to-gain ratio when compared with untreated calves. In two other receiving studies with tilmicosin phosphate using beef steer and bull calves, Duff et al. (2000) reported overall results of no difference ($P > 0.05$) in daily DM intake, ADG, or feed-to-gain ratio compared with untreated calves. In one study by Chirase et al. (2000), tilmicosin phosphate treatment increased ($P < 0.02$) the ADG of newly received beef calves by 37% when compared with untreated calves. Although the improvement in performance due to tilmicosin treatment was inconsistent in all these studies, tilmicosin treatment consistently lowered the number of calves treated for respiratory diseases (Galyean et al., 1995; Duff et al., 2000). Thus, tilmicosin phosphate may have other physiological functions besides antimicrobial activity.

During the entire chronic dust exposure period in the present study, there was an interaction ($P < 0.02$) between dust exposure and tilmicosin phosphate treatment for ADG (Figure 1). The interaction occurred because goats not exposed to dust had higher ($P < 0.02$) ADG when treated with tilmicosin phosphate than those without tilmicosin phosphate. However, when goats were treated with tilmicosin phosphate before exposure to dust events, tilmicosin was not effective ($P > 0.05$) in improving ADG, suggesting that tilmicosin provided very little improvement in performance in the presence of chronic manure dust events. It has

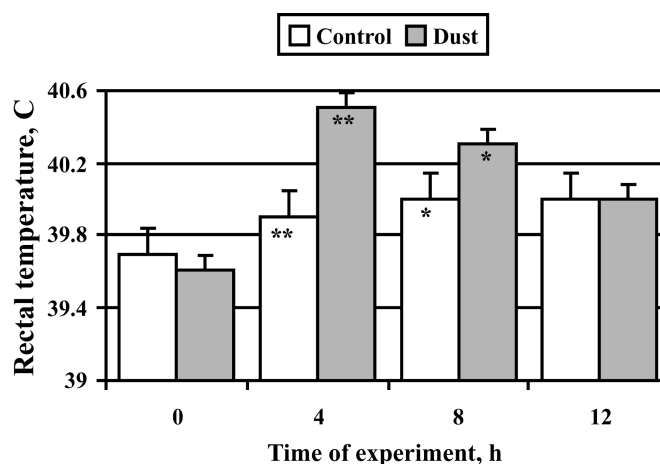


Figure 2. The interaction of dust \times time ($P < 0.05$) after a single 4-h cattle feed yard manure dust exposure event on the RT (rectal temperature, $^{\circ}\text{C}$) of young Spanish goats. Values indicated by asterisks within that hour differ (* $P < 0.05$; ** $P < 0.002$).

been postulated by Purdy et al. (2002) that tilmicosin phosphate might have some antibacterial activity on some Gram-negative bacteria, which have been found to be the main source of the endotoxin in manure dust. Thus, the improvement in ADG by tilmicosin phosphate could have been reduced as a result of the presence of bacteria and/or endotoxin in manure dust.

Rectal Temperature Response

There was no dust \times tilmicosin phosphate treatment interaction ($P > 0.05$) for rectal temperature of goats either during the single or chronic dust exposure phases. However, there was dust \times time interaction ($P < 0.05$) for rectal temperature. Figure 2 represents the rectal temperature changes of goats after the first single dust event. At 4 and 8 h after the dust event, goats exposed to dust indicated higher ($P < 0.002$) rectal temperatures than the control animals, suggesting that the dust increased rectal temperature shortly after exposure. However, rectal temperatures of both dust treatment groups were not different ($P > 0.05$) at 12 h. Further, the rectal temperature measurements for both treatment groups at 20, 44, 68, and 210 h were not different ($P > 0.05$; data not shown), suggesting that the pyrogenicity (fever promotion) resulting from a single manure dust event was temporary because no differences were detected in rectal temperature measured regularly for 210 h. Purdy et al. (2002) suggested that the change in rectal temperature of sheep exposed to simulated cattle manure dust events could be due partly to the endotoxin content of the dust. Olenchock (1994) reported a temporary increase in temperature after a single dose of endotoxin in humans.

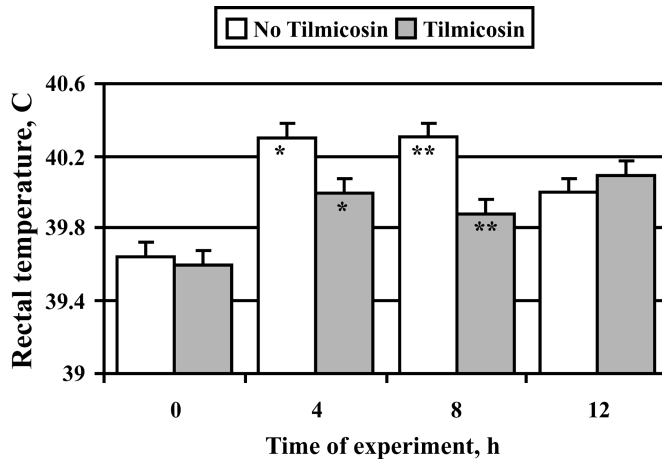


Figure 3. The interaction of tilmicosin phosphate \times time ($P < 0.05$) after a single 4-h cattle feed yard manure dust exposure event on the fever response (rectal temperature, °C) of young Spanish goats. Values indicated by asterisks within that hour differ (* $P < 0.05$; ** $P < 0.01$).

Rectal temperature is often used as a confirmation of morbidity in newly received beef calves (Cummins and Rosenquist, 1980; Chirase et al., 1994; Galyean et al., 1995) and in sheep (Purdy et al., 2002), justifying treatment with antibiotics for microbial infection. Consequently, a single dust event could create false-positives of acute respiratory disease when rectal temperature is measured on the same day as a dust event and used as confirmation of respiratory morbidity. This could result in less judicious and expensive use of antibiotics for the treatment of acute respiratory infections.

There was tilmicosin phosphate \times time interaction ($P < 0.05$) for rectal temperature of goats. Figure 3 represents the effects of tilmicosin phosphate treatment on the rectal temperature of goats. The tilmicosin-treated group had lower ($P < 0.05$) rectal temperatures at 4 and 8 h compared with goats not receiving tilmicosin phosphate. However, rectal temperatures measured at 12, 20, 44, 68, and 210 h were not different ($P > 0.05$) between the tilmicosin phosphate treatment groups (data not shown). Tilmicosin phosphate treatment suppressed the rectal temperature increases of goats. It is possible that tilmicosin phosphate suppressed some Gram-negative bacteria (common in cattle feed yard manure dust), which are primarily the source of endotoxin (Purdy et al., 2002). Thus, the antibacterial activity of tilmicosin phosphate could have reduced rectal temperatures in the tilmicosin phosphate treated goats.

Figure 4 shows the RT of goats during the first 2 d of chronic dust exposure (d 16 and 17). There was time \times dust exposure interaction ($P < 0.05$) for rectal temperature of goats during the first 2 d of chronic dust exposure (Phase II). Goats exposed to dust on

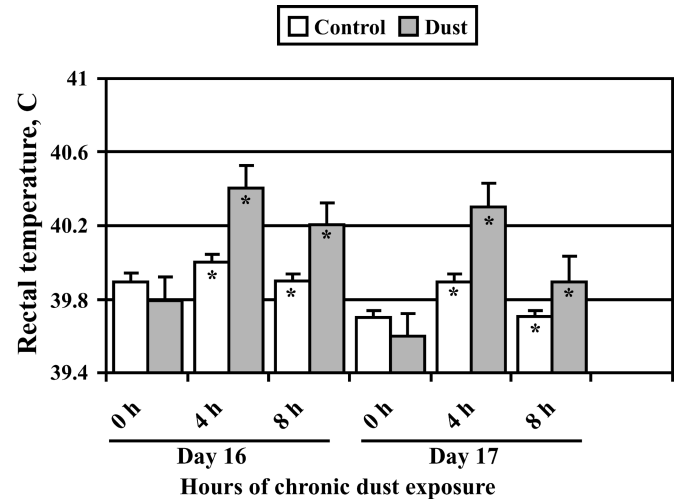


Figure 4. Effect of chronic cattle feed yard manure dust exposure (d 16 to 17) on the fever response (rectal temperature, °C) of young Spanish goats. Values indicated by asterisks within that day and hour differ ($P < 0.05$).

both days had significantly higher ($P < 0.05$) rectal temperatures at 4 and 8 h than the control animals, which was similar to the response observed during the single dust event. These results also agree with those reported in sheep exposed to manure dust events by Purdy et al. (2002). Rectal temperatures of goats for both dust treatment groups were not different on all other subsequent times measured. It seems that after 2 d of chronic dust exposure (including 1 d of single exposure) the rectal temperature response decreased. Again, these observations suggest that the pyrogenicity of manure dust in goats was temporary (Olenchok, 1994).

There was no effect ($P > 0.05$) in tilmicosin phosphate treatment of goats when they were chronically exposed to dust after the first single dust event response had subsided (data not shown). It is possible that by the time the goats were chronically exposed to manure dust (i.e., 15 d after administering tilmicosin phosphate treatments), the effectiveness of tilmicosin phosphate in reducing rectal temperature was reduced, resulting in no benefit to the treated goats.

Acute Phase Reactant Proteins

During the single dust exposure period, goats exposed to dust had a 30% increase in blood fibrinogen concentrations (mg/100 mL) at 4 h after exposure, which was 10 times greater ($P < 0.03$) than the 3% increase in the control goats (data not shown). No other differences ($P > 0.05$) were observed between the dust treatment groups during this phase. In addition, no differences ($P > 0.05$) were observed in serum fibrinogen concentrations between the dust treatment group and those not exposed to dust during the chronic dust

exposure phase. Dust particles vary in shape, size, and biological content (e.g., endotoxin); thus, they could act as or mimic proinflammatory factors by stimulating antigenic receptors. Antigenic receptor stimulation could result in macrophage recruitment (Gimble, 1997) and their secretion of proinflammatory cytokines (Adler et al., 1994), such as tumor necrosis factor- α , interleukin-1, and interleukin-6. Phagocytic cells also produce other proinflammatory mediators, such as prostaglandins, leukotrienes, superoxide, hypochlorous acid, hydrogen peroxide, and nitric oxide (Adler et al., 1994; Gimble, 1997). We propose that the production of these prooxidant molecules (superoxide, hypochlorous acid, hydrogen peroxide, and nitric oxide) during low antioxidant capacity and high lipid peroxidation (Chirase et al. 2000), when they are not properly detoxified by antioxidant mechanisms, could damage healthy tissues. Although lung lesions have been observed at slaughter (Wittum et al., 1996) in cattle that had not previously been treated for bovine respiratory disease and that these lesions affected production (Wittum et al., 1996; Bryant et al., 1999), manure endotoxin exposure has not been proposed as a partial explanation for their occurrence. In addition to the induction of acute phase reactant protein synthesis by the liver, proinflammatory cytokines also activate T and B cells and induce fever responses (Gimble, 1997). Thus, the antigenic stimulation of the respiratory tract by dust particles/endotoxin or other exogenous substances or pathogens has the potential of inducing two general responses: proinflammatory response and immune response (Gimble, 1997).

Packed cell volumes (%) were lower ($P < 0.05$) in goats exposed to dust compared to those in the control group at 44 (30.2 vs. 34.4%; SEM = 1.07; respectively) and 210 (32.8 vs. 36.2%; SEM = 0.89; respectively) h after the single dust exposure event. However, during the chronic dust exposure period, no differences ($P > 0.05$) were detected in packed cell volume between the dust treatment groups.

Similarly, goats exposed to dust had lower ($P < 0.05$) blood hemoglobin concentrations at 44 (9.1 vs. 10.5 mg/100 mL; SEM = 0.50; respectively) and 210 h (9.3 vs. 10.6 mg/100 mL; SEM = 0.26; respectively) after the first single dust exposure event. Blood hemoglobin concentrations were not different ($P > 0.05$) at all other times measured. Blood hemoglobin concentrations were not different ($P > 0.05$) between the dust treatment groups during the chronic dust exposure period.

Total White Blood Cell Counts

Table 2 shows white blood cell (WBC) counts ($\times 1,000$) of goats exposed to simulated manure dust. During the single dust/endotoxin exposure event, the total WBC counts of dust-exposed group were higher at 12 ($P < 0.07$) and 20 h ($P < 0.02$) compared with the goats not exposed to dust. The temporary increase (or redistribution) in leukocytes after manure dust/endotoxin

Table 2. Effect of cattle manure ambient particulate matter (dust) on white blood cell counts (numbers/ μ L) of young Spanish goats

Treatment			
Item	Control	Dust	SE ^a
Single dose			
Time, h			
0	14,740	16,478	966
4	15,381	14,796	1,054
12	15,477 ^b	19,473 ^c	1,401
20	13,681 ^d	17,589 ^e	1,047
44	15,016	14,297	981
68	13,551	15,323	1,089
210	15,996	15,891	1,060
Multiple dose			
Time, h			
Day 16			
4	14,955 ^d	18,361 ^e	921
8	14,543 ^d	18,700 ^e	990
12	15,045 ^f	21,403 ^g	1,238

^aStandard error of least squares means ($n = 6$).

^{b,c}Within a row, means without a common superscript differ ($P < 0.05$).

^{d,e}Within a row, means without a common superscript differ ($P < 0.02$).

^{f,g}Within a row, means without a common superscript differ ($P < 0.003$).

exposure has been reported in sheep (Purdy et al., 2002). Dust exposure \times time interaction for this phase tended ($P < 0.08$) to be different. The presence of an antigen in the blood could lead to the production of WBC in order to fortify the body against the antigen (Kimball, 1998). The mechanisms of acquired immunity are twofold: humoral immunity and cell-mediated immunity (Kimball, 1998). Furthermore, an increase in WBC could be an indicator of invasion by a foreign object or infectious agent, hence the mobilization or activation of effector cells.

Similarly, the WBC numbers were higher in the dust-exposed goats compared with those not exposed at all hours measured on the first day of the chronic dust exposure period (Table 2). However, on all other days measured, the WBC counts were not different ($P > 0.05$) between dust exposure treatments (data not shown). Thus, an apparent adaptation to the dust/endotoxin exposure occurs after repeated exposure (Purdy et al., 2002).

Simulated dust exposure of goats increased ($P < 0.02$) total blood lymphocytes compared with control animals (3,883 vs. 2,530 cell/ μ L; SEM = 401; respectively). Changes in the numbers of blood lymphocytes within 210 h after a single dust event could be due to actual increases in cell numbers or to cell redistribution or repartitioning within tissues. Changes in blood lymphocyte counts could be attributable to inflammatory effects of the dust particles or their endotoxin content. The outer cell membrane of all Gram-negative bacteria is composed of lipopolysaccharide molecules

called *endotoxins* (Luderitz et al. 1978). The toxic portion of endotoxin is the lipid-A portion (Luderitz et al., 1978). Endotoxin (20 to 300 µg) infused directly into human respiratory system was shown to be pyrogenic and caused tightness of the chest (Rylander et al., 1989; Rylander, 1997). Evidence of the effects of endotoxin on cellular and humoral immunity has been reported by several researchers (Pernis et al., 1961; Olenchock, 1994; Rylander, 1997). Increases in peripheral total leukocyte counts and neutrophils were observed 6 h after inhalation of endotoxin (30 to 60 µg in a delivery of 4.5 to 8.1 mL Hanks balanced salt solution) in humans (Clapp et al., 1993).

During the chronic dust exposure period, there were no differences ($P > 0.05$) detected in the number of blood lymphocytes between the dust treatment groups, suggesting that the blood lymphocytes changes were temporary (data not shown).

The dust treatment μ time interaction for eosinophil counts was not different ($P > 0.05$) during the single dust exposure event. However, goats exposed to dust had higher ($P < 0.02$) total blood eosinophil counts than the control animals (37 vs. 12 cells/µL; SEM = 2.13; respectively), which was similar to the blood lymphocyte response. Again, dust exposure had no effect ($P > 0.05$) on blood eosinophils during the chronic dust exposure phase, but eosinophil numbers declined ($P < 0.05$) in exposed goats when compared with pretrial values, suggesting that the changes observed were temporary. The response in blood monocyte counts as a result of a single dust event was inconsistent (data not shown). Again, during the chronic dust exposure period, dust treatment had no effect ($P > 0.05$) on blood monocyte counts (data not shown).

Implications

Ambient particulate matter size, shape, composition, and distribution are variable, but dust events are perceived as being important in animal performance and health. Simulated cattle feed yard manure dust exposure did not decrease the performance of goats. However, dust events transiently increased rectal temperature and altered white blood cell counts in goats. The pyrogenicity observed during an initial simulated dust event was consistent and could contribute to confusion over diagnosing of acute bovine respiratory disease if rectal temperature is used to confirm acute respiratory morbidity. These results suggest that the effects of manure dust events on animal performance and health require additional investigation as an essential component of animal health.

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